Trials and Tribulations of IDP Capture on MIR and Analyses

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Introduction:

Space stations like Russia's Mir provide an excellent platform for capturing interplanetary dust particles/cosmic dust particles (IDP/CDP). A collaborative effort between NASA's Ames Research Center and France's University of Paris, supported by the SETI Institute and Lockheed Martin Missiles and Space Company (LMMS) assembled and flew IDP capture modules containing silica aerogel from early October 1995 to early February 1996 as part of EUROMIR, an European Space Agency experiment[(1)] on Mir. Details of the engineering, fabrication, testing, and shipping of the aerogel were presented at the 27th Lunar Planetary Science Conference (LPSC), entitled, Aerogel for IDP Capture: Lessons Learned[(2)]. This paper summarizes what has been learned from the flight of the aerogel modules and preliminary engineering and chemical analysis of the recovered modules. Strict handling procedures were followed to ensure that any detected changes in the recovered modules including contamination, resulted from the space station environment, or from shipping (packing material), or from the captured particles.

Results:

The initial physical (visual) examination of the modules were done in a 10,000 class clean room. When the module covers were removed, the integrity of the module/aerogel was verified, it survived shipping, launch, orbital exposure, and recovery without apparent structural problems, except for stretching of the platinum retainer wires. This probably resulted when entrained air in the aerogel could not escape quickly enough to equalize the internal and the rapidly decreasing external pressures during launch, thus causing the aerogel to bulge and the wires to stretch. But, the wires effectively held the aerogel in the mold.

The cosmetic surface blemished areas noted in reference 1, resulted during initial assembly when quartz rods used to press the aerogel into the mold adhered to the aerogel. These areas in the recovered modules appeared noticeably darker and rougher whereas the clear surfaces appeared unaffected. Later microscopic examination of the surfaces confirmed the initial visual observations, that the blemished areas are indeed rougher and darker. This condition adversely affects impact detection in these areas. Thus, this assembly problem should be corrected for future missions. These initially blemished areas are susceptible to the space environment with ozone probably causing the erosion and darkening. Surface and subsurface aerogel samples were taken from the modules while in the clean room for analyses to detect chemical changes and contamination.

Following the physical examination, the modules were taken to LMMS' x-ray tomography facility to scan for particulate impacts. Unfortunately, use of low-melting alloy as the adhesive, (to hold the aerogel in the mold) made this examination technique impractical, the lead in low-melting alloy requires high voltage settings for adequate x-ray penetration resulting in reduced resolution. Removal of the aerogel from the mold and low-melting alloy will solve this problem but, was not elected at this time because to protect the aerogel during the subsequent analyses described below.

The collectors were scanned using an automated microscopic scanning system at the University of California at Berkeley. The system was originally developed to quickly and efficiently locate etch-pits in track-etch detectors due to galactic cosmic rays and relativistic heavy ions, and has been in use for that purpose for several years[(3)]. Several candidate impact points with tracks were found and are being analyzed by the x-ray probe technique[(4)] at Brookhaven National Laboratory.

Preliminary chemical and x-ray probe analysis results are summarized here. Organic chemical analysis of the aerogel surface samples showed high levels (2 percent) of contamination by dioctyl adipate a plasticizer. This was an unanticipated finding and no reports on this contaminant as a

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concern for orbital experiments were found in the literature. Analyses of additional samplings from the modules confirmed these high surface contamination levels. Interior samples showed that the contamination was confined to the surface, and did not migrate. Table 1 shows the chemical analyses results for the samples taken from the two modules flown and from a control module.

Preliminary x-ray fluorescence spectra results from a x-ray probe of a 0.25 mm track found by microscopic scanning failed to detect particulate matter at the end of the track but, the presence of "chondritic" elements Ca, Fe, Ni, Mn, Ti, and Cr that could indicate the breakup of a pyroxene particle, although small amounts of Pb, Zn, Cu, Sr, and Zr strongly suggest an orbital debris particle or other contamination possibilities.

Closing Comments:

Valuable insights were gained into the manufacturing, fabrication, and use of aerogel for building a successful IDP/CDP capture instrument from this flight experiment. Aerogel as a capture media performed as expected; it is robust and holds together even under IDP/CDP impact, launch and ground handling loads. It also does not appear susceptible to migration of surface contaminants. But as expected with experiments, not all questions were answered and new questions have arisen for example: where did the high concentration of dioctyl adipate come from? Is it unique to Mir or a quirk of this particular flight? Is it a general problem to be expected in orbital operations? Do particles especially at the micron or tens of micron size, survive capture, and how will these micron size particles and their tracks be found and analyzed cost effectively? The scanning method is probably the best technique available at this time, but it is time and equipment intensive, translating into high analytical cost. Further scanning development emphasizing faster (for surface areas as much as 200x larger), greater focal depth capability (accommodate larger surface irregularities), and better resolution of micron size particle impact holes/tracks are required. Further developmental testing of the x-ray probe technique to validate analytical procedures and data is also required.

Table 1: Aerogel Contaminants (ppm)

Aerogel Samples*	Methanol	Octene	Aliphatic Ester	Acetone	Dioctyl Adipate	Others	Total
A	311	770	128	26	21,544	637	23,416
B	163	1570	692	81	16,229	1,229	19,963
B-1	236	23	131	22	0	93	505
C	84	0	0	7	0	34	125
C-1	406	0	6	107	0	616	1,135
Comm.	174	19	95	159	0	3,134	3,581

Legend: *Samples; A: Space exposed 10 days surface sample, B: Space exposed 4 months surface sample, B-1: Space exposed interior sample, C: As manufactured and cleaned sample, C-1: same as C, stored 1 year and used for shipping simulation test sample and Comm.: commercial grade aerogel of unknown history sample.

References:

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3. A. J. Westphal and Y. D. He, Physics Review Letter 71, 1160 (1993).

4. G. Flynn et al., In-Situ Chemical Analysis of Extraterrestrial Material Captured in Aerogel, 27th LPSC, Pg. 369 & 370, JSC, Houston, TX, March 18-22, 1996.